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Application of bioflocculants produced by *Prestia megaterium* for drinking water purification

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ABSTRACT

Quality water is a scarce commodity in the developing countries. This paper aims to evaluate the application of bioflocculants produced by *Priestia megaterium* (accession number: ON184360) for drinking water purification. A total of twenty-four water samples from stream, ponds and wells were collected in sterile containers from four different Local Government Areas of Niger State, Nigeria. Each sample was treated with varying concentrations of bioflocculant and chemical flocculant (0.05, 0.1, 0.15, 0.2 and 0.5 mg L^{-1}). The microbiological and physicochemical characteristics of the treated and untreated water were determined using standard methods. The results show that water samples from stream, ponds and wells treated with the bioflocculant significantly reduced the microbial load and the physicochemical properties of the water reduced to an acceptable limit, which has practical significance for the safety of drinking water in developing countries. The bioflocculant was effective in aggregating suspended particles and thus, proved its potential to be used as alternative flocculant in the drinking water treatment process.

1. Introduction

Water is the most crucial natural resource required for the proper functioning of life on Earth (Popkin et al., 2010; Pradinaud et al., 2019; Ochilova et al., 2021). The human body's water content is estimated to be around 65 %, making it the most abundant solvent in existence (Montgomery, 2002; Lorenzo et al., 2019). Water constitutes around 71 % of the Earth's exterior area, with the ocean comprising 96 % of it (Brini et al., 2017; Issac and Kandasubramanian, 2021). About 3.5 % of the Earth's water reserves represents the remaining water bodies like groundwater, lakes, rivers, and streams (Kummu et al., 2011; Voss et al., 2013; Mishra, 2023; Musie and Gonfa, 2023). A significant amount of water for drinking, irrigation, and industries is obtained in rural areas through wells, ponds, or streams in the absence of piped water (Nair et al., 2013; Adesakin et al., 2020; Bazaanah and Mothapo, 2024). Although water is abundant on the surface, the quality of freshwater worldwide is a major issue. Streams are particularly vulnerable to carrying municipal and industrial wastewater, as well as run-off from agricultural land in their large drainage basins (Khalid et al., 2018; Bashir et al., 2020). The scarcity of quality water is a significant problem in developing nations. It is a vital environmental resource in both urban and rural areas, as it is essential for daily living. The need for water has had a significant impact on urban development in developing countries, where population concentration has led to severe constraints on resources (Omarova et al., 2019; Suthar et al., 2021; Ingrao et al., 2023).

A report by the World Health Organization (WHO) and United Nations Children's Fund (UNICEF) states that above two billion persons are living in nations where water is scarce, with 700 million persons being taken over by severe drought by 2030 (WHO, 2019; UNICEF, 2023). The issue of standard water quality is a significant concern in developing nations, like Nigeria. In Nigeria, around 70 million individuals lack access to safe drinking water, increasing the consumption of various

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water sources including contaminated water sources (Galadima et al., 2011). The data from UNICEF show that 70 % of Nigeria's water supply is contaminated, which develops from poor effluent supervision, fertilizer and agricultural drainage, hazardous waste from industries, mineral extraction waste, slaughterhouse liquid waste or petroleum exploration (Galadima et al., 2011).

Flocculation is said to be used to separate solid from liquid substances in industrial procedures like sewage treatment, treatment of drinking water, food, and fermentation techniques (Okaiyeto et al., 2016; Badawi et al., 2023). The scattered particle clusters are made possible by the reduction or elimination of stability in suspensions of colloids. Typically, flocculants are classified as inorganic (aluminium trichloride $AlCl_3$), organic synthetic (polyethyleneimine) as well as naturally occurring flocculants (plant-based) (Okaiyeto et al., 2016; Abu Tawila et al., 2018). The growth phase of microorganisms produces macromolecular polymers known as bio-flocculants, which can aggregate suspended solids like cells and colloidal substances without causing harm or degradability (Li et al., 2020; Jiang et al., 2021).

The decomposability, non-poisonous properties, and lack of secondary contamination from breaking down intermediates make bio-flocculants the preferred choice over flocculants like alum in water treatment. Several microorganisms like bacteria, algae, fungi, and actinomycetes are regarded as bio-flocculants producing microorganisms. The bacterium *Priestia megaterium* is a Gram-positive organism that thrives in different environments and produces spores. By using it, a flocculating agent can be created to treat contaminated water (Oyewole et al., 2023). This study was conducted to determine the use of bio-flocculants derived from *Priestia megaterium* (accession number ON184360) for drinking water purification.

2. Materials and methods

2.1. Study area

Four Local Government Areas (LGA) were involved in the study area. Fig. 1 illustrates the locations of Chanchaga, Paikoro, Bida, and Bosso LGA in Niger State, Nigeria. Minna is the capital city of Niger State, which is situated in the North-Central geopolitical zone of Nigeria. Chanchaga is one of the 25 LGAs in Niger State, Nigeria. The land area of 72 km^2 is occupied by 201,429 individuals (Idowu et al., 2020). The estimated population of 208, 212 is in Bosso LGA, which covers 1, 592 km^2 as of 2019, and a 2.5 % growth rate is projected. Bosso Local Government is located at 9° 39′ 12“ North and 6° 30’ 58” East (Idowu et al., 2020). With a total area of 2066 km^2, the Paikoro LGA is home to an estimated population of 158,086 (Ahmed et al., 2020). Bida city lies on the A124 motorway. At the 2006 census, Bida LGA measures 51 km^2 in size and had a population of 188,181 (Ahmed et al., 2020). At 9° 4′ 59, the city is located at the North and 6° 1′ 0.0012″ at the East (Mahmud and Umaru, 2018).

The sample stations for stream, well and pond water used for this research is presented in (Supplementary Table, ST 1).

2.2. Sample collection and transportation

The *Prestia megaterium* (accession number ON184360) used in this study was obtained from the culture collection in our laboratory and as

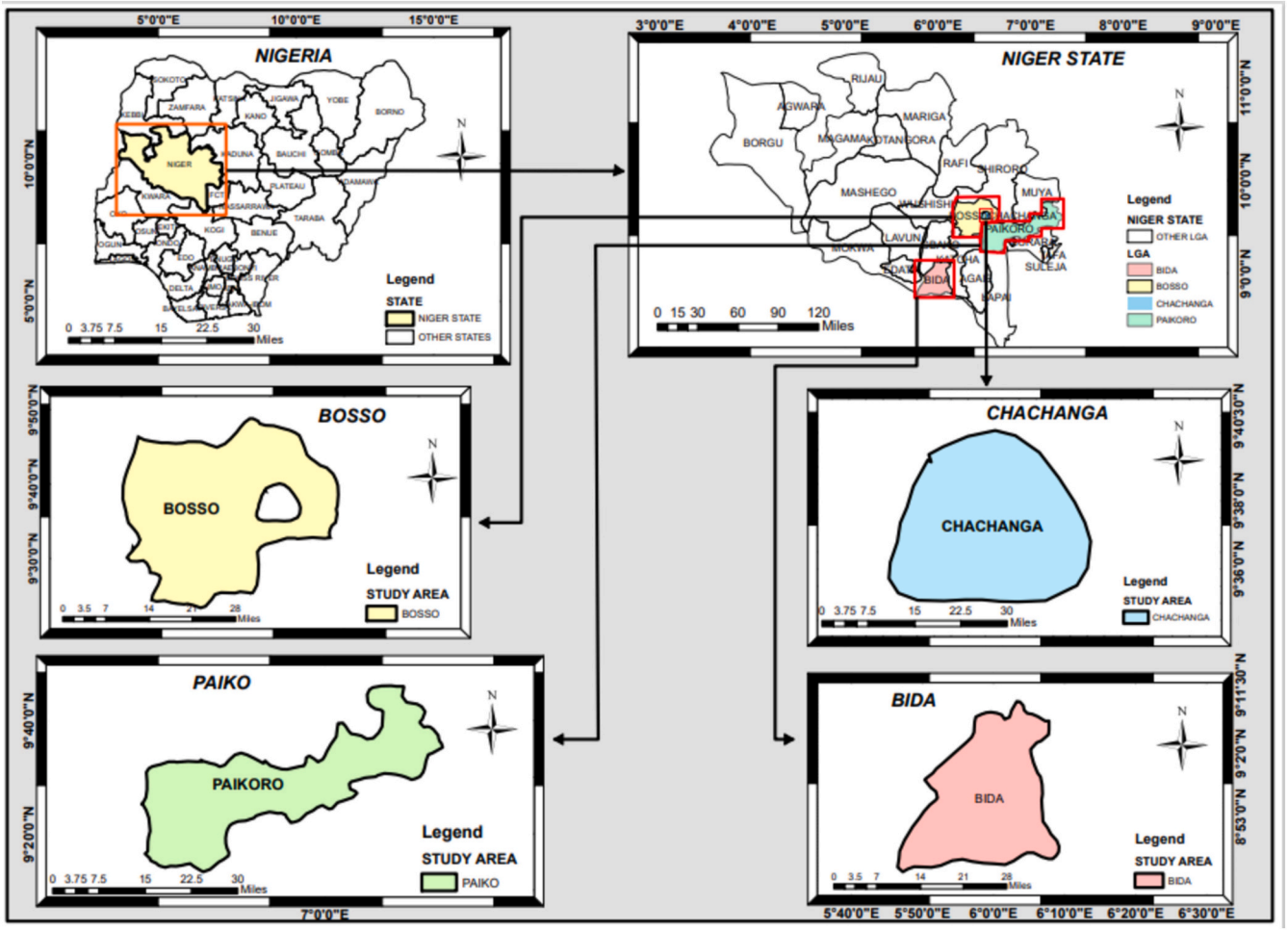

Fig. 1. A Map displaying LGAs situated in Niger State, Nigeria. Source: Department of Geography, Federal University of Technology Minna, Niger State, Nigeria.

previously reported (Oyewole et al., 2023). Sterile plastic water sample bottles were used to collect water samples (well, stream and pond) from four LGAs in Niger State and was conveyed in an ice pack to the laboratory in the Department of Microbiology, Federal University of Technology Minna, Niger State, Nigeria for further investigations.

2.3. Bioflocculant preparation and characterization

The bioflocculants were produced by *Prestia megaterium* using the methods previously described (Oyewole et al., 2023) and extracted with 70 % ethanol using a ratio 1: 2 of biofloculant to ethanol. The bioflocculants were characterized using Cary 630 Fourier transform infrared (FTIR) (Agilent Technologies, Model no - MY19322004, Malaysia) (Luo et al., 2014). The bioflocculant was also characterized by Scanning Electron Microscopy (SEM). Bioflocculant sample was covered in 20 nm carbon using a Quorum Q150R ES mini sputter coater, then staged on drywall with adhesive carbon and examined at 15KV in high vacuum using an Oxford XMax 50 Silicon Drift Energy Dispersive x-ray detector that is fit into Phenom PRO-X SEM (Kumar et al., 2014; Rasulov et al., 2017).

2.4. Microbiological analysis

Bacteria were isolated in three different culture media; Nutrient agar, Eosin Methylene Blue (EMB) and MacConkey agar and were utilized to count the total bacterial population and total enteric bacteria. The media were prepared following the manufacturer's instructions. The water sample was diluted using tenfold dilution in 10 test tubes that contained 9 mL of sterile distilled water each. To dilute the water sample, 1 mL of 10^1 was added to the mixture using some sterile syringes. Then 1 mL of it was mixed with 9 mL samples of 10^2, then a 1 mL of 10^2 was mixed with 9 mL of 10^3, then 10^4, and finally, 1 mL of 10^9 mixed with 9 mL of 10^{10}. The sterilized nutrient agar was allowed to sit until it reaches a temperature of 45 °C. Using pour plate method, 1 mL of serially diluted sample was transferred to a sterile Petri dish with a syringe. Warm liquid media were gently poured onto the sample surface in the Petri dish and completely covered. The Petri dish was gently swirled to allow equal spread of the agar and sample, and then it was left to gel by allowing the Petri dish to sit unmoved on 'a flat surface'. The Petri dishes were turned upside down and incubated at 37 °C for 24 h.

2.5. Physicochemical analysis of the water samples treated with bioflocculant and alum

The water samples were subjected to different concentrations (0.05, 0.10, 0.15, 0.20 and 0.50 mg L^{-1}) of bioflocculant and alum in 1000 mL flask. The water samples were subjected to a vigorous swirling process at 1500 rpm/min for five minutes using centrifuge 80–2 (China) to create an even mixture. The mixture was allowed to settle for fifteen minutes. The top part was emptied into a different flask to obtain a treated water and the sediment was poured off.

Six physicochemical parameters: temperature, pH, electrical conductivity, chemical oxygen demand, total dissolved solids, and biochemical oxygen demand of the water samples were determined using the methods of American Public Health Association (APHA) (2005).

2.6. Data analysis

One-way analysis of variance (ANOVA) using IBM SPSS version 23 was used to analyse the data obtained from this study. The data was presented as means±standard deviation of duplicates.

3. Results

3.1. The characteristics of the bioflocculant

The bioflocculant displayed typical COOH (peak 3287.51197 cm^{-1}), OH^- (peak 1457.38909 and 1457.38909 cm^{-1}), amine (peak 1174.11142 cm^{-1}) (FTIR spectra of Supplementary Fig. 1) and white flakes that characterize a bioflocculant (Supplementary Fig. 2). As the magnification increased, the presence of the white flakes was more noticeable.

3.2. The bacteriological parameters of water sources from Chanchaga, Bosso, Paikoro and Bida LGA of Niger State

The total bacterial count of treated and untreated stream water samples at different concentrations of bioflocculant and alum from the four different locations sampled (i.e. Chanchaga, Bosso, Paikoro and Bida) is presented in Fig. 2a (Supp. Table 2). The microbial count ranged from 2500 CFU mL^{-1} to 130,500 CFU mL^{-1} at a bioflocculant concentration of 0.05 to 0.2 mg L^{-1}. Chemical flocculant had a microbial count in the range of 2500 to 130,500 CFU mL^{-1} at a concentration of 0.05 to 0.2 mg L^{-1} while the microbial count of untreated water sample ranged from 40,000 CFU mL^{-1} to 276,543 CFU mL^{-1}.

The total bacterial count of treated and untreated pond water samples at various concentrations of bioflocculant and alum from the four different locations sampled (i.e., Chanchaga, Bosso, Paikoro and Bida) is shown in Fig. 2b (ST. 3). The water sample treated with 0.5 mg L^{-1} bioflocculant had the lowest total bacterial count of 3600 and 30,500 CFU mL^{-1} for Chanchaga and Bida respectively while Bosso and Paikoro had the least count of 36,000 and 13,000 CFU mL^{-1} at bioflocculant concentration of 0.1 mg L^{-1} and 0.05 mg L^{-1} respectively. The untreated water samples had a bacterial count that ranged from 59,500 to 147,500 CFU mL^{-1} respectively.

The total bacterial number of treated and untreated well water samples at different concentrations of bioflocculant and alum from the four different locations sampled is shown in Fig. 2c (ST. 4). The microbial count per CFU mL^{-1} range from 0 to 6500 CFU mL^{-1} at concentration of 0.05 to 0.5 mg L^{-1}. The sample treated with 0.5 mg L^{-1} bioflocculant had the lowest total bacterial count of 300, 1250 and 3350 CFU mL^{-1} for Chanchaga, Paikoro and Bida respectively while Bosso had its least bacterial count of 1300 CFU mL^{-1} at a concentration of 0.2 mg L^{-1}. All four locations had the least concentration of chemical flocculant at 0.5 mg L^{-1}. The total bacterial count for untreated water ranged between 500 and 1100 CFU mL^{-1}.

3.3. Physicochemical properties of stream water sample

Results of physical and chemical properties of water samples obtained from various LGAs in Niger State are presented. Fig. 3a (ST. 5) shows the physicochemical variables of the stream water sample from Bida. The physical and chemical properties of treated water showed a range of pH from 3.72 to 7.12, EC 299.00 to 483.50 μs/cm, COD of 8.00 to 40.00 mg L^{-1}, BOD range of 8.50 to 11.50 mg L^{-1}, TDS of 4.20 to 5.10 mg L^{-1} and temperature of 29.10 °C.

The physicochemical parameter of the stream water sample from Paikoro is shown in Fig. 3b (ST. 6). The physical and chemical properties of Paikoro stream water sample showed varying temperature range of 27.80–28.45 °C, pH of 3.52–6.99, EC of 221.00–881.50 μs/cm, COD range of 12.00–20.00 mg L^{-1}, BOD range of 6.50–11.00 mg L^{-1} and TDS range of 1.05–2.90 mg L^{-1}. The physical and chemical assessment of treated and untreated Chanchaga stream water sample is presented in Fig. 3c (ST. 7). The temperature of stream water sample was 27.10 °C, pH 3.52–6.92, EC 139.00–758.00 μs/cm, COD range of 8.00–28.00 mg L^{-1}, BOD range of 8.00–14.00 mg L^{-1}, TDS range of 0.15–1.40 mg L^{-1}. The treated and untreated physical and chemical components of the stream water sample from Bosso is presented in Fig. 3d (ST. 8). A

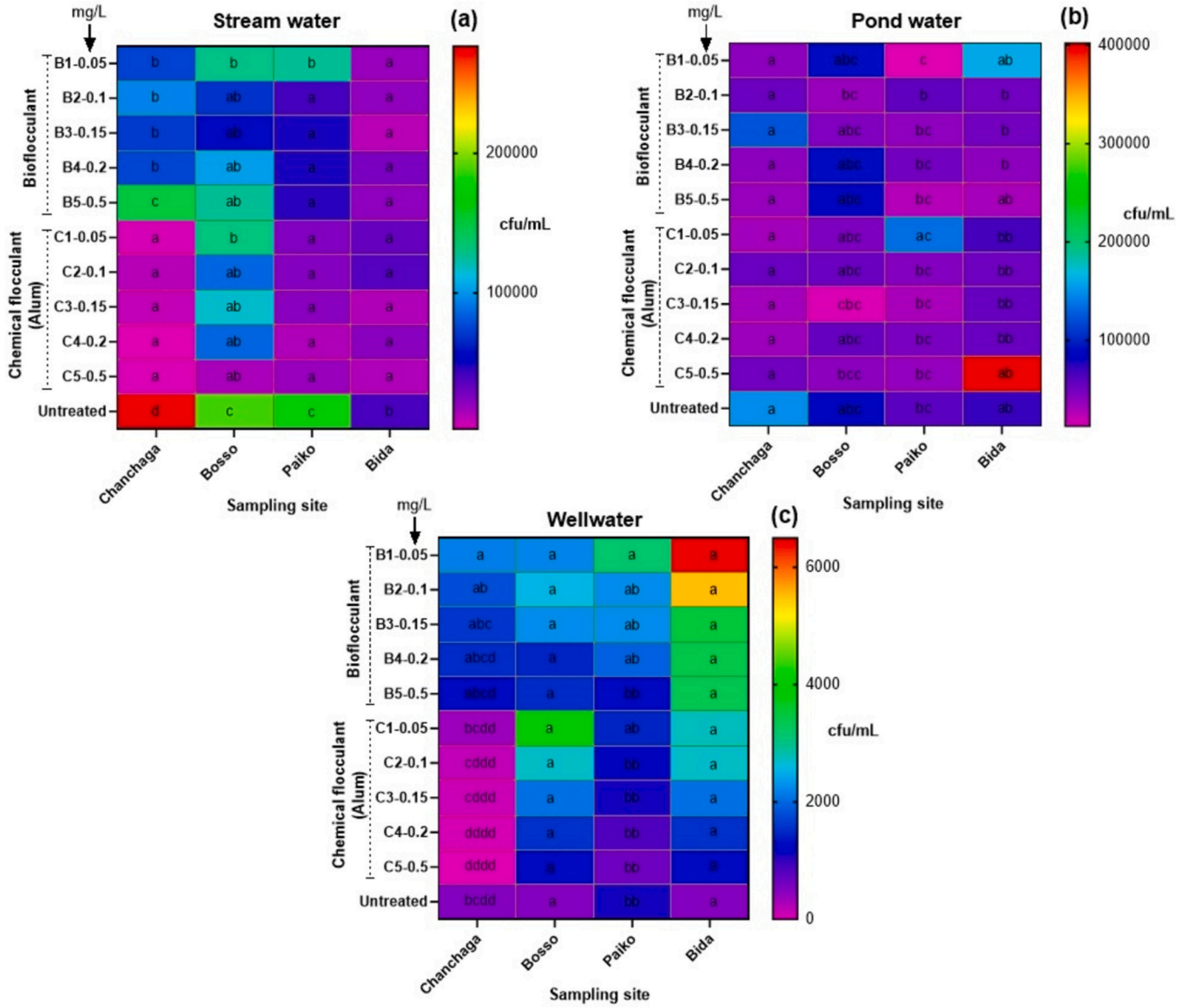

Fig. 2. The total bacterial count of treated and untreated stream water (a) pond water (b) and well water (c) samples at different concentrations of bioflocculant and alum. Parameters with different letters (a, b, c, and d) are significantly different ($p < 0.05$).

temperature of 29.10 °C was recorded in Bosso stream. pH range of 3.72–7.12, EC of 280.00–867.50 μs/cm, COD range of 8.00–20.00 mg L^{-1}, BOD range of 8.50–11.50 mg L^{-1} and TDS range of 4.20–5.10 mg L^{-1}.

3.4. The physicochemical assessment of treated and untreated pond and well water

The physicochemical assessment of treated and untreated pond water sample from Chanchaga is shown in Fig. 4a (ST. 9). The physicochemical properties of the Chanchaga pond water showed a temperature range of 28.10–29.00 °C, pH range of 3.91–7.73, EC range of 51.50–368.00 μs/cm, COD range of 16.00–32.00 mg L^{-1}, BOD range of 3.00–5.50 mg L^{-1} and TDS range of 6–11.5 mg L^{-1}. Fig. 4b (ST. 10) shows the physicochemical values of treated and untreated pond water sample from Bosso. Bosso's pond water showed a physical and chemical properties range of temperature 28.55–32.75 °C, pH 6.18–8.21, EC 231–453 μs/cm, COD 12–44 mg L^{-1}, BOD 4.5–12.5 mg L^{-1} and TDS 6.5–34.5 mg L^{-1}.

The physicochemical assessment of treated and untreated pond water sample from Paikoro is shown in Fig. 4c (ST. 11). Paikoro pond water showed a physicochemical property of temperature, with the range of 28.85–29.05 °C, pH 5.78–7.69, EC 209.5–609 μs/cm, COD 12–28 mg L^{-1}, BOD 4–8.5 mg L^{-1} and TDS 6–127 mg L^{-1}. Fig. 4d (ST. 12) shows the physicochemical values of treated and untreated pond water sample from Bida. Bida pond water showed a physicochemical property of temperature, with the range of 27.9–28 °C, pH ranges between 5.03 and 6.54, EC 137.5–171.5 μs/cm, COD 15–52 mg L^{-1}, BOD 4.5–36.5 mg L^{-1}, and TDS 9.5–112.5 mg L^{-1}.

Fig. 5a (ST. 13) shows the Physiochemical assessment result of treated and untreated well water sample from Paikoro. The physical and chemical properties of Paikoro well water sample showed a temperature range of 30.00–30.70 °C, pH 3.53–6.94, EC 237.50–426.00 ±107.48 μs/cm, COD range of 9.30–11.15 mg L^{-1}, BOD range of 7.00–12.00 mg L^{-1}, TDS range of 0.35–4.30 mg L^{-1}. Fig. 5b (ST. 14) showed physiochemical assessment result of treated and untreated well water sample from Bida. Bida well water showed a physical and chemical property of temperature, ranging between 30.00 and 32.25 °C, pH 3.48–6.82, EC 129.50–316.50±μs/cm, COD range of 9.90–48.005 mg L^{-1}, BOD range of 2.50–7.50 mg L^{-1}, TDS range of 2.05–74.00 mg L^{-1}.

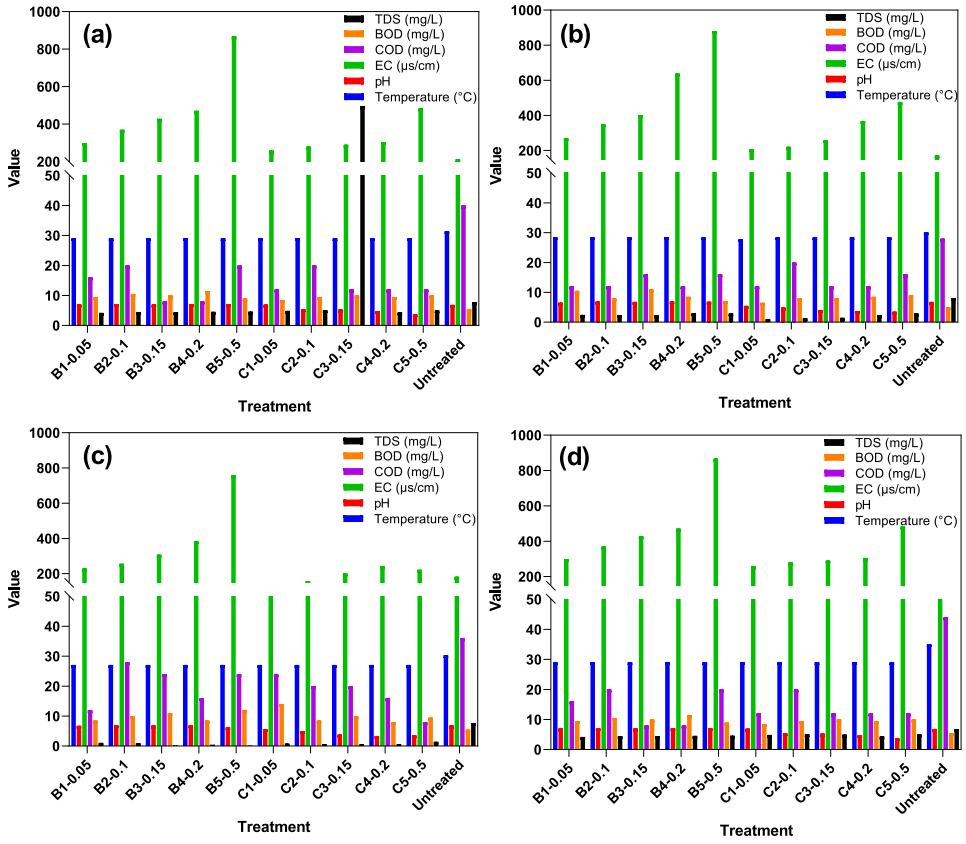

Fig. 3. Physicochemical analysis results of treated and untreated Stream water sample from Bida (a), Paikoro (b), Chanchaga (c), and Bosso (d). Results presented in Alluvial Diagram with correlations and proportions. B1-B5 are bioflocculant of different concentrations (mg L^{-1}); and C1-C5 are chemical flocculant of different concentrations (mg L^{-1}).

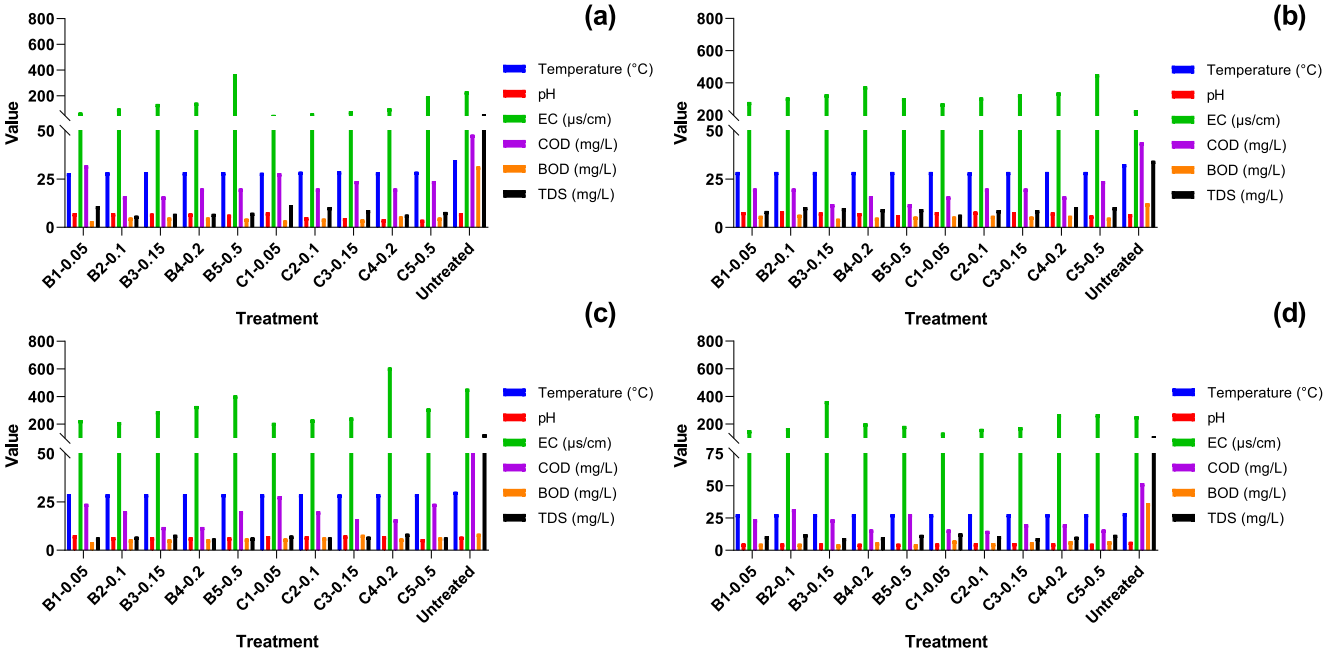

Fig. 4. Physicochemical analysis results of treated and untreated Pond water sample from Chanchaga (a), Bosso (b), Paikoro (c), and Bida (d). B1-B5 are bio-flocculant of different concentrations (mg L^{-1}); and C1-C5 are chemical flocculant of different concentrations (mg L^{-1}).

Fig. 5c (ST. 15) shows the physiochemical assessment result of treated and untreated well water samples from Bosso. Physical and chemical properties of Bosso well water showed a temperature of 30 °C, pH of 6.02–7.38, EC of 447.50–617.00 µs/cm, COD range of 8.40–11.30 mg L^{-1}, BOD range of 4.50–8.00 mg L^{-1}, TDS range of 1.45–7.45 mg L^{-1}. The physiochemical analysis result of treated and untreated well water

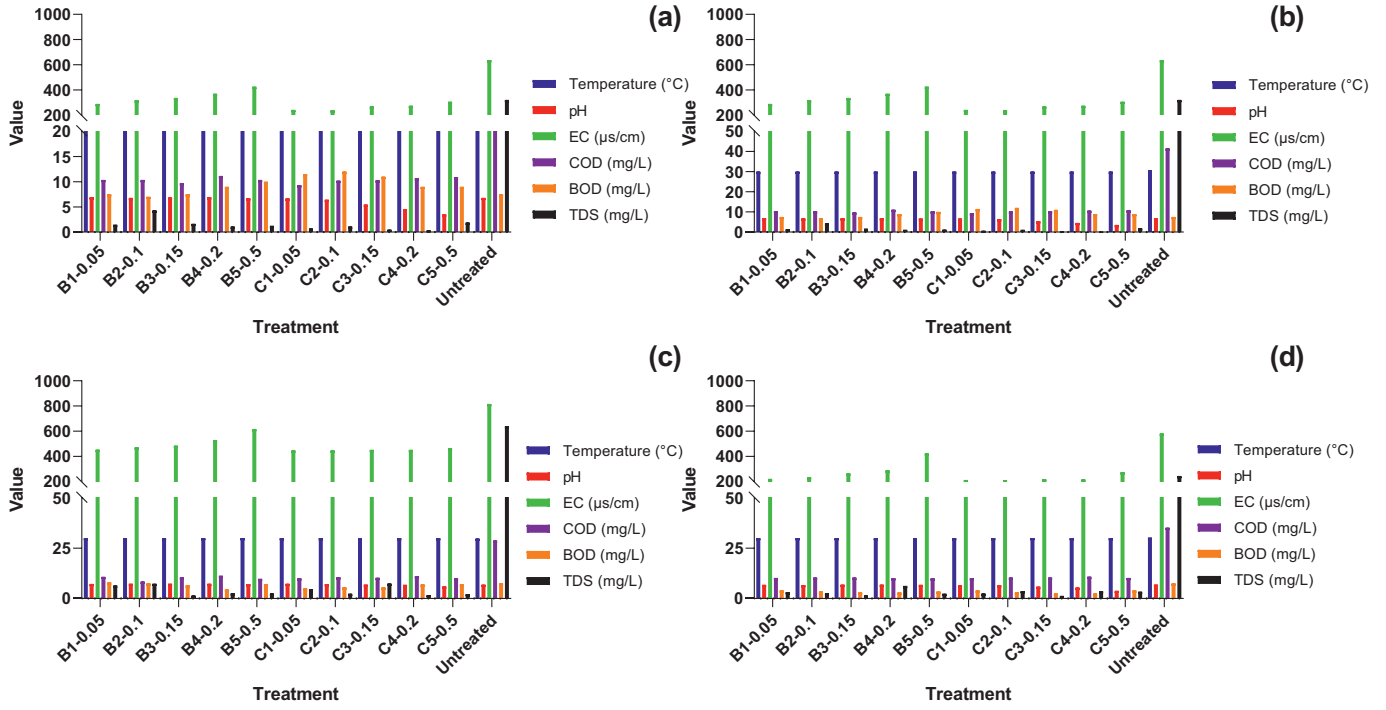

Fig. 5. Physiochemical assessment results of well water at Paikoro (a), Bida (b), Bosso (c), and Chanchaga (d). Arrow marks in each panel indicates the values of untreated sample. [Each data set has the values of 11 treatments: B1-B5 + C1-C5 + Untreated sample. B1-B5 are bioflocculant of different concentrations (mg L^{-1}); and C1-C5 are chemical flocculant of different concentrations (mg L^{-1})].

samples from Chanchaga is shown in Fig. 5d (ST. 16). Chanchaga well water showed a physicochemical property of temperature, ranging between 30 and 30.25 °C, pH 3.85–6.92, EC 210.50–423.00 μs/cm, COD range of 10.00–10.90 mg L^{-1}, BOD range of 2.50–4.00 mg L^{-1}, TDS range of 1.30–6.25 mg L^{-1}.

4. Discussion

The adequacy of water on Earth's surface poses a significant global issue, as the drainage basins that carry metropolitan and unwanted water from industries and agricultural runoff are crucial sources of fresh water (Bashir et al., 2020). Microbiological components of stream, pond and well water from Chanchaga, Bosso, Paikoro and Bida LGA of Niger State, Nigeria were determined to investigate the effects of varying concentrations of bioflocculant from *Prestia megaterium* (accession number: ON184360) on the water samples. Treatment with different concentrations of various flocculants resulted in significant differences ($p < 0.05$) in the microbial load of the water samples. Notwithstanding, the numerous studies conducted on bioflocculants, their application remains limited by their flocculation activity and cost. The water sample treated with bioflocculant in this study at concentration of 0.15 mg L^{-1}, revealed the lowest bacterial number of 71,500 CFU mL^{-1} for Chanchaga, 54,500 CFU mL^{-1} for Bosso and 11,000 CFU mL^{-1} for Bida, while Paikoro had the lowest number of bacteria of 41,000 CFU mL^{-1} at 0.1 mg L^{-1} treated with bioflocculant. For chemical flocculant treatment, lowest number of bacteria was shown at 0.2 mg L^{-1} concentration for Chanchaga with 2500 CFU mL^{-1}. Bida recorded 12,500 CFU mL^{-1} bacterial count at 0.15 mg L^{-1} Bosso recorded 14,500 CFU mL^{-1} at 0.5 mg L^{-1}, and Paikoro with the lowest count of 13,000 ± 6000 CFU mL^{-1} at 0.2 mg L^{-1}. The highest bacterial count was recorded for untreated water, with Chanchaga, having the highest number of 276,543 CFU mL^{-1} while the count of 40,000 CFU mL^{-1} was from Bida.

The water treatment with bioflocculant and alum exhibited different microbial counts in the water samples, which is lower compared to the untreated water samples. From the four different locations sampled (i.e., Chanchaga, Bosso, Paikoro and Bida), the microbial count (CFU mL^{-1}) range from 13,000 to 402,000 at a concentration of 0.05 mg L^{-1} to 0.5 mg L^{-1}. The water sample treated with bioflocculant at 0.5 mg L^{-1} concentration was used to treat water and recorded the lowest number of bacteria for Chanchaga (36000) and Bida (30500) CFU mL^{-1} accordingly. Well water sample treated with bioflocculant concentration of 0.5 mg L^{-1} had the least total bacterial count of 1300, 1250 and 3350 CFU mL^{-1} for Chanchaga, Paikoro and Bida respectively while Bosso had its least bacterial count at a concentration of 0.2 mg L^{-1}. All the four locations had the least bacterial count at 0.5 mg L^{-1} concentration of the chemical flocculant. The total bacterial count for untreated water ranged between 500 and 1100 CFU mL^{-1}. The total bacterial population in treated well water was significantly higher than that in untreated well-water at $p < 0.05$.

The removal of *Escherichia coli, Staphylococcus aureus, Pseudomonas aeruginosa, Candida albicans,* and *Aspergillus niger,* from water or effluent is believed to be effective by *Prestia megaterium*, with rates varying from 80 to 99 %. Oyewole et al. (2023), reported that *Prestia megaterium* can also eliminate other contaminants like heavy metals, dyes and organic matter from effluents or water as a bioflocculant. The results of this investigation are comparable to those of bioflocculants produced by *Bacillus licheniformis* and *Serratia ficaria* (Gong et al., 2008).

The assessment and classification of water quality rely on the physical and chemical characteristics of all the four water sources, as identified by Sharma et al. (2020), including the temperature. The World Health Organization (WHO) (2006) recommended that temperatures of treated water fall within 22 to 30 °C standard level. Elevated temperatures of 30.15–35.05 °C was noticed at the area where samples were collected. The outcome was contrary to Selepe and Maliehe's findings where they reported that at 40 °C, the bioflocculant-producing strain achieved the highest yield of biofilm (Selepe and Maliehe, 2024). Temperature fluctuations for drinkable water are likely to be influenced by daytime sunlight exposure and inadequate storage of the water. Temperature is mainly affected by atmospheric and weather conditions (Vargas et al., 2021). Some reactions in the body may be accelerated by

higher water temperatures. Anaerobic reaction reduces the solubility of oxygen and increases smell. The elevated temperatures of the untreated water sample in this study may be due to the seasonal temperature increase during sampling. Water bodies may become warmer due to a combination of solar radiation, pristine air quality, altitude, and lower water level. The growth of microorganisms and the deteriorating activities are heightened by the elevated temperature of water, which can lead to a rise in water taste, smell, colour, and corrosion issues (Veronis, 1972). The temperature may also affect the flocculation and aggregation process of bioflocculants, especially under high or low temperature range. Temperature may determine how amenable suspended particles can be towards aggregation of suspended particles.

Water's acidity and alkalinity are gauged by its pH value (Skotta et al., 2023). Water standard is closely linked to the chemical standard of water through its pH value (Veronis, 1972). The present study revealed that there was a significant difference ($P < 0.05$) in the pH values of the four water samples acquired from the various sample locations, at varying concentrations (0.05, 0.10, 0.15, 0.20, and 0.50 mg L^{-1}). The acceptable pH limit of the World Health Organization (WHO) are within a range of 6.5–8. The findings also revealed that the pH of water treated with varying concentrations of alum showed different acidic pH range. The WHO and Nigeria Standard for Drinking Water Quality (NSDWQ) are met by 0.05 mg L^{-1} concentration, higher concentrations fall below an acceptable level. The pH value ranging from 3.35 to 6.99 were recorded, which showed that chemical flocculant used to treat the water samples were somewhat acidic. The pH can reach extremes due to low water alkalinity, inadequately cured cement mortar pipe linings or treatment breakdowns, and accidental spills. The pH of water can be influenced by biologic procedure such as water treatment (Nkosi et al., 2021).

The ability of water to conduct electricity is quantified by electrical conductivity (Manoj et al., 2022). Water electrical energy can be used as a reliable measure of its total salt (Nugraha et al., 2020). A significant difference ($p < 0.05$) was noticed in this study as the electrical energy of the water sample (treated) varied with different concentrations of alum and bioflocculant. A flocculant concentration resulted in the electrical conductivity of the treated samples. The untreated sample had values exceeding 1000 Us cm^{-1} of NSDWQ, while the bioflocculant treatment had acceptable values and the chemical flocculant treatment had a lesser value below the accepted values. The samples' electrical conductivity was within the <1250 μs/cm standard recommended by the WHO for drinking water when administered. The electrical energy of water is directly linked to the amount of dissolved mineral matter. The findings of this study suggest that water samples subjected to bioflocculants and chemical flocculants were weakly and highly mineralized. The conclusion of this study agrees with the work of Skotta et al. (2023).

Nugraha et al. (2020) used the measurement of TDS to determine the combined content of all abiotic and biotic material in liquid that is either molecular, oxidized, or micro-granular suspended in nature. Abiotic salts and a small quantity of biotic matter in solution are known as total dissolved solids. Polluted water is characterized by an excess of dissolved solids. The total dissolved solids of water samples were found to be significantly different. If water is dissolved in it, the taste may be affected. The quality of drinking water and its levels of TDS have been determined, with grades ranging from excellent (<300 mg L^{-1}); good (300 and 600 mg L^{-1}); fair (600 and 900 mg L^{-1}); poor (900 and 1200 mg L^{-1}) and unacceptable (>1200 mg L^{-1}). The TDS level can be elevated by agricultural practices and certain geological features. Surface water contamination can be caused by untreated effluents and wastewater from domestic and industries, leading to elevated TDS levels in water bodies (Agoro et al., 2020).

The oxygen consumption of microorganisms during the decomposition of organic matter at a specified temperature in aerobic conditions is known as biochemical oxygen demand (BOD) (Nugraha et al., 2020). The accepted BOD limit for quality drinking water according to WHO is <5 mg L^{-1}. The study shows that the treated water was a little above the WHO-acceptable standard. A BOD_5 is the quantity of oxygen that microorganisms use during the breakdown of organic matter in the presence of air at specified temperatures. This study revealed elevated BOD levels, which suggests a significant amount of microbial load in samples of water being examined. The BODs were employed as a standard of water cleanliness with values below 1–2 mg L^{-1} being considered clean, those >2–3 mg L^{-1} being classified as justly clean, 5 mg L^{-1} uncertainly clean and 10 mg L^{-1} surely bad and contaminated.

The quantity of oxygen that can be taken in by reactions in a measured solution is indicated as chemical oxygen demand (COD) (Geerdink et al., 2017). Its function is to indicate the composition of reducing elements like biotic, nitrite, as well as ferrous salts in water. The accepted COD limit for quality drinking water according to WHO is 10 mg L^{-1}. The study shows that some bioflocculant-treated water, particularly those at 0.15 mg L^{-1} and 0.20 mg L^{-1} were within the WHO-acceptable standard. The water treated by the bioflocculant had a lower COD value than the water treated by the chemical flocculant. The COD levels were found to be much higher in the untreated water sample than in the treated samples. Biotic materials contributed to the COD values noticed in this present study (Geerdink et al., 2017).

5. Conclusions

In this study, bioflocculant was produced using *Priestia megaterium* ON184360 and was used to aggregate suspended solids in water sources (stream, ponds, underground well) from four Local Governments Areas in Niger State (Chanchaga, Bosso, Paikoro and Bida), Nigeria. The bioflocculant displayed typical characteristics of bioflocculant with COOH, amine peaks and white flakes. The water sample treated with 0.5 mg L^{-1} bioflocculant had the lowest total bacterial count across all the LGAs. The physicochemical properties (temperature, pH, EC, COD, BOD, TDS) of water treated with bioflocculant competed favourably with water treated with chemical flocculant (alum) used as positive control. The bioflocculant's efficacy in reducing pollutants allowed it to be employed as an alternative in water treatment processes. The bioflocculant produced by *Priestia megaterium* was effective in aggregating suspended particles in this study and thus, proved its potential to be used as substitute in the drinking water treatment process.

CRediT authorship contribution statement

Oluwafemi Adebayo Oyewole: Supervision, Conceptualization. **Asmau Mohammed Maude:** Writing – original draft, Investigation. **Japhet Gaius Yakubu:** Writing – review & editing. **Desire Elechi Phillip:** Investigation. **Abideen Ajibola:** Investigation. **Patience Emmanuel:** Investigation. **Olabisi Peter Abioye:** Project administration. **Olalekan David Adeniyi:** Writing – review & editing. **Evans Chidi Egwim:** Supervision, Methodology. **Naga Raju Maddela:** Writing – review & editing, Software.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.biteb.2024.101997.

Data availability

The data used have been included in the manuscript

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